

Jan. 1, 1957

J. A. LEE ET AL

2,776,014

TOOL FOR FRACTURING EARTH FORMATIONS

Filed Dec. 14, 1953

2 Sheets-Sheet 1

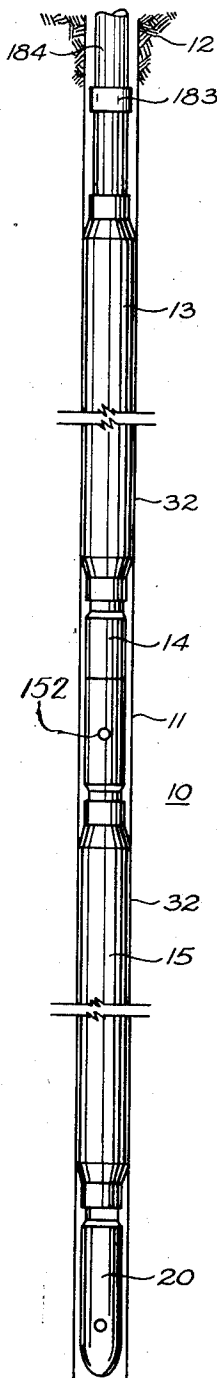


Fig. 1

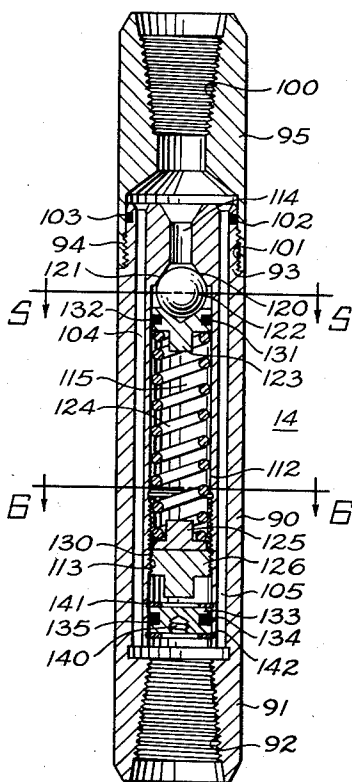


Fig. 4

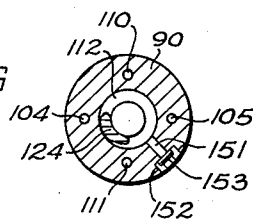
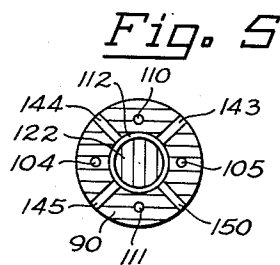


Fig. 6

JOHN A. LEE
HARRY A. BARCLAY
MALCOLM O. JOHNSON
INVENTORS

BY *Frederick E. Dumoulin*
ATTORNEY

Jan. 1, 1957

J. A. LEE ET AL

2,776,014

TOOL FOR FRACTURING EARTH FORMATIONS

Filed Dec. 14, 1953

2 Sheets-Sheet 2

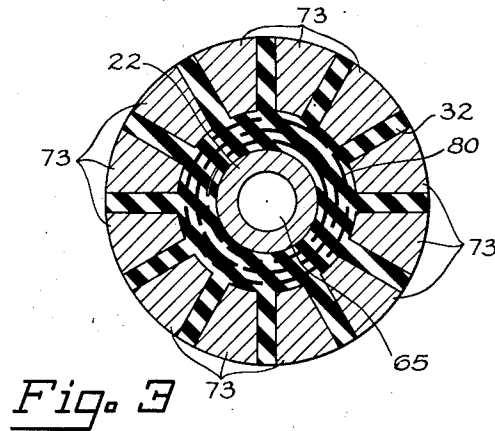
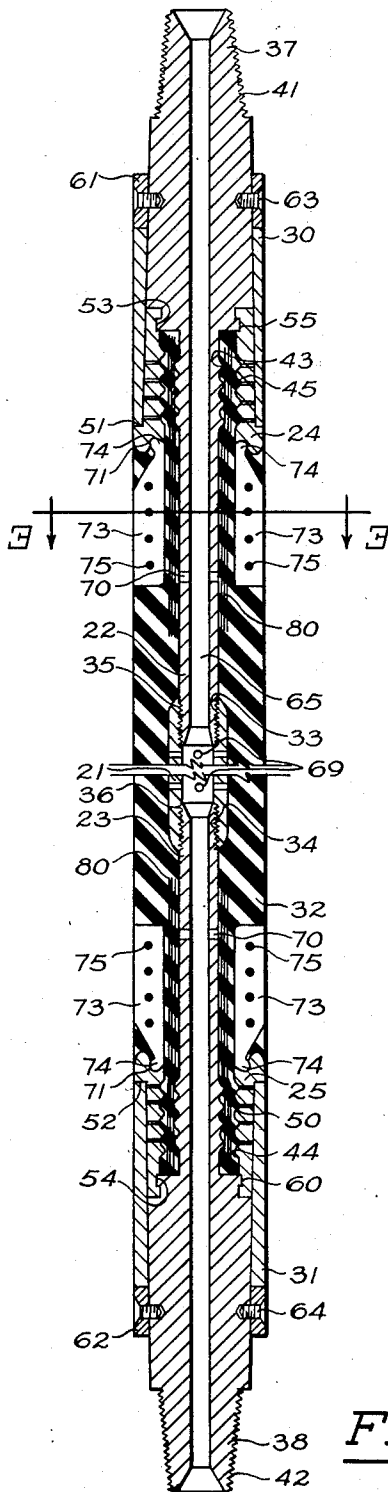


Fig. 3

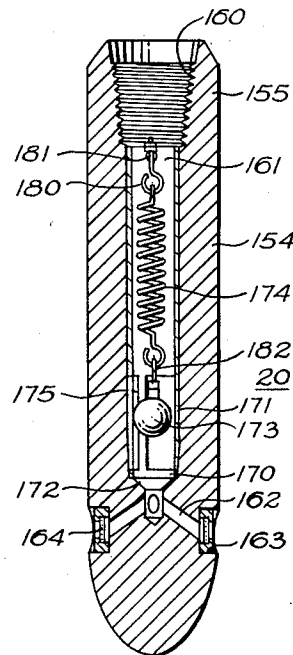


Fig. 7

JOHN A. LEE
HARRY A. BARCLAY
MALCOLM O. JOHNSON
INVENTORS

BY *Frederick E. Dumoulin*
ATTORNEY

Fig. 2

1

2,776,014

TOOL FOR FRACTURING EARTH FORMATIONS

John A. Lee, Harry A. Barclay, and Malcolm O. Johnson, Dallas, Tex., assignors, by mesne assignments, to Soncony Mobil Oil Company, Inc., a corporation of New York

Application December 14, 1953, Serial No. 397,966

4 Claims. (Cl. 166—177)

This invention relates to well tools and relates more particularly to a tool for fracturing earth formations penetrated by a well bore hole.

In the production of fluids such as water, gas, or petroleum oil from an earth formation penetrated by a well bore hole, the rate of flow of fluid from the formation to the well bore hole depends upon, among other factors, the permeability of the formation. In the past, the earth formations have been treated to increase their permeability and hence the rate of flow of fluid to the well bore hole by employing explosives or acids to create fractures or channels in the formation. Recently, a new technique has been employed for increasing the permeability of an earth formation. This technique involves setting off the formation by packers and forcing a liquid into the well bore hole between the packers at a sufficiently high pressure to cause fracturing of the formation. However, with all of these methods, control of the location and direction of the fractures or channels has been difficult or impossible. It has also been proposed to create fractures or channels in the formation by means of a tool positioned in the well bore hole alongside the formation but the effectiveness and operation of these tools have left much to be desired.

It is an object of this invention to provide a tool for fracturing earth formations. It is another object of this invention to provide an improved tool for the treatment of earth formations to increase the ease of fluid flow. It is another object of this invention to fracture earth formations at controlled locations within well bore holes. It is another object of this invention to create vertical fractures in earth formations penetrated by a well bore hole. Other objects of the invention will become apparent from the following description thereof.

Figure 1 is a vertical view of a tool constructed in accordance with a specific embodiment of the invention.

Figure 2 is an enlarged vertical sectional view of one of the boot sections of the tool.

Figure 3 is a horizontal sectional view along the line 3—3 of Figure 2.

Figure 4 is an enlarged vertical sectional view of the flow section of the tool.

Figure 5 is a horizontal sectional view along the line 5—5 of Figure 4.

Figure 6 is a horizontal sectional view along the line 6—6 of Figure 4.

Figure 7 is an enlarged vertical sectional view of the valve section of the tool.

Referring to Figure 1, the tool thereof, indicated generally by the numeral 10 and illustrated in position in a well bore hole 11 in the earth 12, comprises a boot section 13, a flow section 14, another boot section 15, and a valve section 20. As shown, the boot sections are in their expanded position.

Boot sections 13 and 15 are similar in construction and, referring now to Figures 2 and 3, each section comprises generally tubular central member 21, tubular end mem-

2

bers 22 and 23 connected to the tubular central member 21 to form a unitary tubular member, collars 24 and 25, sleeves 30 and 31, and expensible, flexible boot 32. The boot surrounds the entire length of the tubular central member 21 as well as the ends of the tubular end members contacting the tubular central member. As will be observed from Figures 1 and 2, the longitudinal dimension of boot 32 is greater than its lateral dimension. Preferably, the longitudinal dimension of the boot is at least ten times the lateral dimension of the boot. The tubular central member is provided at each end with internal threads 33 and 34. The tubular end members 22 and 23 are provided with external threads 35 and 36, respectively, which cooperate with threads 33 and 34, respectively, to maintain the tubular end members connected to the tubular central member. The tubular end members 22 and 23 are provided at each of their other ends with tapered pin sections 37 and 38, respectively, and the tapered pin sections 37 and 38 are provided with external threads 41 and 42, respectively. Approximately at their central sections, the tubular end members 22 and 23 are provided with a plurality of external ridges 43 and 44, respectively. The collars 24 and 25 are of the split type and are provided with a plurality of internal ridges 45 and 50, respectively. Sleeves 30 and 31 fit over the tubular end members 22 and 23 and over the collars 24 and 25, respectively, and abut against shoulders 51 and 52 on collars 24 and 25, respectively. Collars 24 and 25 are maintained in position with respect to the tubular end members 22 and 23 by means of grooves 53 and 54 into which tongues 55 and 60, respectively, of the tubular end members fit. Rings 61 and 62 surround the tubular end members and abut against the sleeves 30 and 31, respectively. The rings 61 and 62 are maintained in position by means of a plurality of screws 63 and 64, respectively, and thus serve to maintain the collars and the sleeves in position. Channel 65 extends throughout the length of the tubular member 21 and the tubular end members 22 and 23. The tubular member 21 is provided with a series of fluid ports 69 which are arranged radially about the tubular member and extend from the channel 65 to the surface of the tubular member. The tubular end members 22 and 23 are provided with a series of similar fluid ports 70.

The boots 32 are constructed of a flexible, expansible material capable of retaining its flexibility and expansibility under compressive pressures as high as 15,000 pounds per square inch or more at the maximum temperatures ordinarily encountered in well bore holes. These temperatures are usually not greater than about 350° F., although occasionally higher temperatures will be encountered. A material such as "Hycar" will be found to be satisfactory for the material of the boots.

The split collars 24 and 25 are each provided with groove 71 extending circumferentially around the collars. The boots are provided with a plurality of fingers 73, formed of heavy rigid metal such as steel, which are embedded in and bonded at each point of contact to the material of the boots. The fingers 73, as will be observed from Figures 2 and 3, are relatively thick in order that they will have high beam stress. Their thickness is at least equal to their maximum width. The fingers are disposed longitudinally with respect to the tool and each of the fingers is provided at one end thereof with a tongue 74 movably fitting within the groove 71. Each of the fingers is also provided with a plurality of holes 75 to provide a reinforced union of the fingers and the material of the boots. At the end portion of the boots, a plurality of strips 80 of cloth material such as heavy impregnated canvas duck, overlapping as shown, are incorporated into and bonded with the material of the boots

whereby a greater mechanical strength is provided to the boots at these end portions.

Flow section 14, referring to Figures 4, 5, and 6, comprises tubular member 90 provided at one end with tapered box section 91 having internal threads 92 and provided at the other end with threaded section 93 having external threads 94, and box member 95 having internal threads 100 at one end and internal threads 101 to cooperate with threads 94 at the other end. Threaded section 93 is provided with gasket groove 102 containing O-ring gasket 103. The tubular member 90 is provided with four radially positioned channels 104, 105, 110, and 111 extending longitudinally throughout the entire length of the member and with bore 112 containing internal threads 113 at the lower end thereof.

The bore 112 in tubular member 90 comprises a relatively narrow channel 114 and valve chamber 115. The channel 114 widens at its top portion and passes through the box member 95. Positioned interiorly of the valve chamber 115 is valve 120. Valve 120 comprises valve seat 121 located at the point where channel 114 leads into the valve chamber 115, ball 122 positioned within the valve chamber 115 adjacent to the valve seat 121, ball rest member 123, spring 124 having a predetermined initial compression, rest member 125, and threaded member 126 provided with external threads 130 to cooperate with threads 113. Ball rest member 123 is provided with gasket groove 131 containing O-ring gasket 132. Positioned within valve chamber 115 and closing the lower end thereof is closure member 133 provided with gasket groove 134 containing O-ring gasket 135. The closure member 133 is also provided with threaded chamber 140 to accommodate a tool for inserting and removing the member from the valve chamber and the member is retained within the chamber by means of retaining rings 141 and 142. Leading laterally, as shown in Figure 5, from the valve chamber 115 at the upper end thereof at a point just below the valve seat 121 but above any point reached by the ball rest member 123 with the ball 122 in the valve chamber are four channels 143, 144, 145, and 150. Also leading laterally from the valve chamber 115, as shown in Figure 6, but below any point reached by the ball rest member 123 with the spring 124, the rest member 125, and the threaded member 126 in the chamber, is fluid port 151 permitting imposition of well bore hole pressure on the underside of ball 122. The fluid port 151 leads to a recess 152 in the external face of the tubular member 90 and the recess is provided with a screen 153 retained therein by suitable means, such as screws (not shown).

Valve section 20, referring to Figure 7, comprises a valved closure member 154 for boot section 15 and is provided with tapered box section 155 having internal threads 160 to cooperate with threads 42 of pin section 38 in boot section 15. The closure member 154 is provided with a centrally positioned chamber 161 tapered at its lower end and leading to a plurality of ports 162 extending radially and downwardly to the external face of the closure member. Each of the ports terminates at a recess 163 at the face of the closure member and each recess is provided with a screen 164 retained therein by any suitable means, such as screws (not shown). The valve section 20 is provided with a valve 170 comprising sleeve 171, ball seat 172, ball 173, and spring 174 having a predetermined constant. Sleeve 171 is tapered at its lower end and fits snugly within the chamber 161 and is also provided with a plurality of vertically extending slots 175. The spring 174 is suspended by hook 180 from pin 181 attached to the sleeve and the ball is suspended by hook 182 from the spring.

In one manner of assembling the valve section 20, the screens 164 are fastened within the recesses 163. Pin 181 is attached to the sleeve 171 and hook 180 is connected to the pin. The ball 173 is then hung by hook 182 on spring 174 and the spring is hung onto hook

180. The sleeve is now inserted into the valve chamber 161.

The boot sections 13 and 15 can be assembled by threading the tubular end members 22 and 23 into the tubular member 21. The boots 32 are molded or otherwise formed to the proper shape over the tubular member 21 and the tubular end members, the cloth strips 80 being made an integral part of the boots, the fingers 73 being bonded therein, and the split rings 24 and 25 being in position about the boots are bonded thereto with the tongues 74 of the fingers fitting within the grooves 71 of the rings. The boots are also bonded to the tubular end members at the sections containing the ridges 43 and 44. The sleeves 30 and 31 and the rings 61 and 62 are placed into position and the screws 63 and 64 are inserted and tightened.

The flow section 14 can be assembled by threadedly attaching the box member 95 to the tubular member 90, the gasket 103 being within the gasket groove 102. The ball 122, the ball rest 123 with the gasket 132 within the groove 131, the spring 124, and the spring rest member 125 are placed within the valve chamber 115 and the threaded member 126 is screwed into the chamber. The spring 124, as previously mentioned, and as will be more fully explained hereinafter, has a predetermined initial compression. A control over the initial load on the spring can be effected by the distance the threaded member 126 is screwed into the chamber 115. The retaining ring 141 is placed into position, the closure member 133 is inserted into the chamber, the gasket 135 being in the groove 134, and the retaining ring 142 is then placed in position.

The box section 155 of valve section 20 is threadedly connected to the pin section 38 of the boot section 15, the pin section 37 of the boot section 15 is threadedly connected to the box section 91 of flow section 14, and the box section 95 of the flow section is threadedly connected to the pin section 38 of the boot section 13.

In operation, the tool is lowered into the well bore hole 11 to a position opposite the formation to be fractured, the pin section 37 of the boot section 13 being threadedly connected to the tool joint box 183 at the end of tubing 184. The well bore hole will ordinarily be filled with drilling fluid or other fluid to maintain a hydrostatic pressure on the formations penetrated by the well bore hole. In order that the tool may be lowered into the well bore hole with minimum displacement of drilling fluid, i. e., is run into the well bore hole "wet," spring 174 in valve section 20 is selected to have an initial compression such that the ball 173 normally will be suspended above and unseated from valve seat 172 but such that the ball 173 will be seated in valve seat 172 when the flow of fluid downwardly through the tool and out through the ports 162 exceeds a predetermined rate. For example, the spring 174 may be selected such that the ball 173 will be seated in valve seat 172 when the flow of fluid downwardly through the tool exceeds one barrel per minute. However, the spring can be selected to have a greater compression. Ball valve 170 being open by virtue of the compression of spring 174, the fluid in the well bore hole, as the tool is lowered therein, will enter the ports 162 and flow upwardly through slots 175, channel 161, channel 65 in boot section 15, channels 104, 105, 110, 111 in the flow section 14, channel 65 in boot section 13, and thence into the tool joint 183 and the tubing 184. By virtue of the screens 164, cuttings or other large, coarse particles are prevented from entering into the tool.

When the tool has been lowered to the desired location in the well bore hole opposite the formation to be fractured, hydraulic pressure is imposed upon the column of fluid within the tubing. For this purpose, any suitable type of apparatus capable of pumping fluid at a pressure sufficiently high to fracture the underground formation, such as a positive displacement pump, may be employed.

5

It may be desired to flush at least a portion of the fluid from the tool and the tubing in which case the rate of flow of fluid downwardly within the tubing is maintained below the rate which would cause the ball 173 to seat in the valve seat 172 whereby fluid will flow from the tool through ports 162 to the well bore hole. The pressure on the column of fluid within the tubing is increased with consequent increase in downward rate of flow of fluid. When the rate of flow of fluid exceeds the rate required to overcome the compression of spring 174 attached to the ball 173, valve 170 closes, fluid will no longer flow from the tool, and the pressure within the tool will increase. With the closing of valve 170, the pressure imposed upon the fluid within the tubing forces the fluid through the ports 69 and 70 in the boot sections 13 and 15, causing the boots to expand outwardly and to contact the walls of the well bore hole, as illustrated in Figure 1. As the pressure within the boots is increased, stresses are transmitted to the formation by the expanded boots and when the pressure within the boots has increased to a value such that the stresses transmitted to the formation exceed the tensile strength of the formation plus the effective pressure of the overburden, the formation is fractured at the point of applied stress. Each boot transmits predominantly radial stresses, and the radial stresses applied at neighboring locations in the formation create vertical fractures in the formation extending between the boots.

Following fracturing of the formation by action of the boots and the fluid issuing from the ports in the flow section 14, as will be explained in detail hereinafter, the tool may be moved to a new location within the well bore hole for further fracturing or may be removed from the well bore hole. The pressure on the fluid within the tubing is decreased and when the pressure within the tubing becomes less than the pressure in the well bore hole between the boots plus the compression of spring 124 against ball 122, ball 122 will become seated in seat 121. Ball 173 will become unseated when the pressure of the fluid in the tubing becomes less than the pressure in the well bore hole less the compression of spring 174 and the pressure in the tubing and the well bore hole will become equalized. With equalization of pressure, the boots will collapse and assume their original shape permitting the tool to be removed, and since ball 173 is unseated flow of the fluid through the ports 162 can occur with movement of the tool if the movement is not of such rate as to cause the ball 173 to become seated.

A particular feature of the invention resides in the provision of the fingers 73. Other features of the invention reside in the provision of the ridges 43 and 44 in the tubular end members 22 and 23, respectively, the ridges 45 and 50 in the split collars 24 and 25, respectively, the bonding of the boots to the sections of the tubular end members and the split collars containing the ridges, and the layers of cloth material 80. By provision of these means, the boots are anchored to the tubular end members 22 and 23 and dislodgement therefrom and leakage under the necessarily high pressures employed for fracturing an earth formation are prevented. The boots being bonded to the sections of the split collars and the tubular end members containing the collars, resistance is offered to tearing and to leakage of fluid between the boot and the tubular end members and split collars. Further, the provision of the sections of the collars and tubular end members containing the ridges prevents extrusion of the ends of the boots between the tubular end members and the collars. However, of greatest value in this respect is the provision of the fingers 73. As the boots are expanded and move outwardly from the tubular member 21 and the tubular end members 22 and 23 to contact the walls of the well bore hole, the fingers also move outwardly pivoting on the tongues 74 positioned within the grooves 71 of the split collars. The edges of the fingers upon contacting the walls of the well bore hole provide bridges of high beam stress between the tool and the walls of the well bore

6

hole which bridges are capable of withstanding the pressures within the boots and thereby help to prevent extrusion of the boots into the well bore hole between the walls thereof and the split collars 24 and 25. Additionally, the boots being bonded to the fingers and containing the layers 80 of cloth provide additional mechanical strength to the boots at the end portions thereof to prevent extrusion or bursting.

As previously stated, spring 124 is selected to have a predetermined initial compression and this initial compression is such that ball 122 will become unseated when the pressure within the tool exceeds the pressure within the bore hole by a predetermined amount. This amount may be 1000 pounds per square inch, for example, or may be a greater or lesser amount. When the pressure within the tool exceeds the pressure within the bore hole by the predetermined amount, as by fracturing of the formation or otherwise, and the ball 122 becomes unseated, fluid flows through channel 114 to valve chamber 115 and thence through fluid ports 143, 144, 145, and 150 to the well bore hole. Since the pressure within the boots will be greater than the pressure of the fluid within the well bore hole by the pressure imposed upon ball 122 by the compression of spring 124, the boots will remain expanded while ball 122 is unseated and will continue to transmit stresses to the formation. Further, the boots serve as packers to confine the fluid issuing from the ports 143, 144, 145, and 150 to the portion of the well bore hole between the boots. The fluid issuing from these ports and entering the well bore hole between the boots is at a pressure below the pressure within the boots only by the pressure imposed upon the ball 122 by the compression of spring 124. The fluid, therefore, is capable of entering the fractures initially created by the stresses transmitted by the boots to transmit fluid pressure to the extremities of the fractures and propagate the fractures. Further increases in pressure in the fluid entering the well bore hole between the boots will serve to propagate further the fractures and, since the pressure in the boots is always higher than the pressure of the fluid entering the well bore hole between the boots, the boots will maintain a positive pressure tending to keep the fractures open.

During operation of the tool, a small amount of fluid may flow from the well bore hole into the valve chamber 115 through the port 151. The presence of cuttings or other large, solid particles in the portion of the valve chamber occupied by the spring 124 might interfere with the smooth operation of the spring. However, by providing screen 153 in the recess 152, cuttings or other large, solid particles are prevented from entering the valve chamber through the port 151. Fluids may also enter the valve chamber through ports 143, 144, 145, and 150. However, the amount will be comparatively small and any cuttings or other large core samples will not be able to interfere with the smooth operation of the spring since the ball seat 123 provided with gasket 132 provides a fluid tight barrier between the spring and the ball. Accordingly, screens at the mouths of ports 143, 144, 145, and 150 are not required. However, if desired, the screens may be provided.

The tool may be employed for acidizing of the formation following fracturing if desired. In this use of the tool, a suitable acid mixture containing an inhibitor to prevent attack of the acid on the tubing and metal parts of the tool is pumped through the tubing. The rate at which this acid mixture is pumped may be less at first than the rate which will cause ball 173 to seat whereby any fluid in the tubing below the acid mixture may be pumped out of the tool and tubing. Thereafter, the rate of flow may be increased to cause ball 173 to seat and the pressure thereafter increased to cause the boots to expand and ball 122 to unseat whereby the acid mixture will flow through the ports in the flow section 14 to contact the fractured formation between the boots. In similar manner, the tool may be employed for treatment

of the fractured formation with other fluids. Further, while the tool has been described in connection with its use in increasing the permeability of the formation to increase the flow of fluids therefrom, it may also be used in connection with other operations involving fracturing of an earth formation.

Having thus described our invention, it will be understood that such description has been given by way of illustration and example and not by way of limitation, reference for the latter purpose being had to the appended claims.

We claim:

1. In an apparatus of the character described comprising in combination a flow section having a fluid port leading exteriorly thereof and provided with normally closed valve means capable of opening at a predetermined pressure differential to permit flow of fluid through said port, boot sections comprising a tubular member connected at each end of said flow section and having a port leading exteriorly thereof and a flexible, expansible boot surrounding each of said last named tubular members over the exterior portion thereof and attached thereto at its end portions thereof, said boot having a longitudinal dimension at least ten times as great as its lateral dimension and a valve section comprising a closure member connected at one end of one of said last named tubular members, said valve section having a port leading exteriorly thereof and valve means normally open to permit flow of fluid through said port and capable of closing at a predetermined rate of fluid flow, the improvement comprising a plurality of longitudinally disposed fingers embedded in and bonded to said boots adjacent to said ends thereof attached to said last named tubular members, said fingers having a thickness at least equal to their width.

2. In an apparatus of the character described comprising in combination a flow section having a fluid port leading exteriorly thereof and provided with normally closed valve means capable of opening at a predetermined pressure differential to permit flow of fluid through said port, boot sections comprising a tubular member connected at each end of said flow section and having a port leading exteriorly thereof and a flexible, expansible boot surrounding each of said last named tubular members over the exterior portion thereof and attached thereto at its end portions thereof, said boot having a longitudinal dimension at least ten times as great as its lateral dimension and a valve section comprising a closure member connected at one end of one of said last named tubular members, said valve section having a port leading exteriorly thereof and valve means normally open to permit flow of fluid through said port and capable of closing at a predetermined rate of fluid flow, the improvement comprising collars surrounding each of said boots at the end portions thereof, said collars having finger receiving means therein, and a plurality of longitudinally disposed fingers embedded in and bonded to said boots adjacent to their ends thereof attached to said last named tubular means and movably received within said finger receiving means, said fingers having a thickness at least equal to their width.

3. In an apparatus of the character described com-

prising in combination a flow section having a fluid port leading exteriorly thereof and provided with normally closed valve means capable of opening at a predetermined pressure differential to permit flow of fluid through said port, boot sections comprising a tubular member connected at each end of said flow section and having a port leading exteriorly thereof and a flexible, expansible boot surrounding each of said last named tubular members over the exterior portion thereof and attached thereto at its end portions thereof, said boot having a longitudinal dimension at least ten times as great as its lateral dimension and a valve section comprising a closure member connected at one end of one of said last named tubular members, said valve section having a port leading exteriorly thereof and valve means normally open to permit flow of fluid through said port and capable of closing at a predetermined rate of fluid flow, the improvement comprising collars surrounding each of said boots at the end portions thereof, said collars having a circumferentially extending groove therein, a plurality of longitudinally disposed fingers embedded in and bonded to said boots adjacent to their ends thereof attached to said last named tubular members, said fingers having a thickness at least equal to their width, and a tongue on each of said fingers movably fitting within the groove in said collar surrounding the same end portion of said boots.

4. In an apparatus of the character described comprising in combination a flow section having a fluid port leading exteriorly thereof and provided with normally closed valve means capable of opening at a predetermined pressure differential to permit flow of fluid through said port, boot sections comprising a tubular member connected at each end of said flow section and having a port leading exteriorly thereof and a flexible, expansible boot surrounding each of said last named tubular members over the exterior portion thereof and attached thereto at its end portions thereof, said boot having a longitudinal dimension at least ten times as great as its lateral dimension and a valve section comprising a closure member connected at one end of one of said last named tubular members, said valve section having a port leading exteriorly thereof and valve means normally open to permit flow of fluid through said port and capable of closing at a predetermined rate of fluid flow, the improvement comprising a plurality of strips of cloth incorporated into and impregnated with the material of said boots at the end portions thereof, collars surrounding each of said boots at the same end portions thereof, said collars having finger receiving means therein, and a plurality of longitudinally disposed fingers embedded in and bonded to said boots adjacent to their ends thereof attached to said last named tubular means and movably received within said finger receiving means, said fingers having a thickness at least equal to their width.

References Cited in the file of this patent

UNITED STATES PATENTS

2,235,318	Halliburton	Mar. 18, 1941
2,295,770	Baker	Sept. 15, 1942
2,652,894	Brown et al.	Sept. 22, 1953